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COMPARATIVE CHARACTERISTIC ANALYSIS OF DIESEL ENGINE WITH BIODIESELS

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ABSTRACT

The rapid diminishing of fossil fuel resources, limited in nature and concerns of environment were the reasons for exploring the biodiesel use as petroleum based fuel substitute. Even though biodiesel is gaining worldwide attraction as a proper substitute for petroleum diesel, the suitability of biodiesel in terms of fuel properties and engine characteristic are highly desirable aspects in usage. The present work is focused on the comparative fuel properties analysis of sunflower biodiesel, rice bran oil biodiesel, corn biodiesel and waste cooking oil biodiesel with standard petroleum diesel. The performance and emission characteristics of 3.72 kW diesel engines when running with these biodiesels also studied to test the suitability of these biodiesels to be used in existing diesel engines. The results show that all said biodiesel satisfies fuel properties requirements as per ASTM standards and engine characteristics also show similar to that of diesel operated characteristics. The slightly lower brake thermal efficiency and higher brake specific fuel consumption were observed with these biodiesels compared to petroleum diesel. Higher NO_X and considerable lower HC & CO emissions were obtained with these biodiesels when compared to petroleum diesel.

KEYWORDS: Performance, Emission, Biodiesel & Diesel Engine

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1. INTRODUCTION

Many researchers around the world have explored several alternative fuel resources like biodiesel produced from seed oils and non-edible oils. According to national biodiesel policy, an indicative target of 20% for the blending of biodiesel was proposed. To meet the target, several biodiesels are to be explored and investigate them to check its usability in existing diesel engines without modification in engine design.

The feedstock used for biodiesel production currently are mainly high quality food grade vegetable oils such soya bean oil (mainly USA), rapeseed oil (mainly EUROPE) and palm oil. In India, most of the researchers explored and studied different biodiesels that are derived from vegetable oils mainly Sun Flower BioDiesel (SFBD), Rice Bran oil Biodiesel (RBD), Corn BioDiesel (CBD) and Waste Cooking Oil BioDiesel (WCBD).

Jinlin Xue et al. [1] analyzed "the impact of biodiesel on engine emissions and performance. They reported that the usage of biodiesel contributes to the significant decrease in HC and CO emission, the rise in gas consumption and growth in NOX emission". Also, they mentioned the usage of biodiesel decrease carbon deposition and use of the major engine elements. Thus, the combinations of biodiesel with little content instead of petroleum diesel helps in controlling air pollution and relieving the strain on scares tools without significantly losing engine power and market. Mohd. Yousuf Ali et al. [2] analyzed utilization of cotton seed oil from diesel engines with no alteration with various combinations from 10 – 50 percent in steps of 10% and also reasoned that

combinations around 30% may be successfully utilized to fulfill the brief term gas scarcity. Raheman H. and A. G. Phadatare [3] researched “Diesel engine features using blends (B20, B40, B60, B80, and B100) of Karanja methyl ester and petrol. They observed greater brake thermal efficiency, reduced brake specific fuel consumption and reduced emissions with B20 mix”. H H Masjuki et al. [4] analyzed IDI Diesel engine features using coconut oil mixed (B10, B20, B30, B40 and B50) gas at several speeds. The best Engine attributes were detected in motor speed of 1600 rpm for many fuels. The operation and emission characteristics effects revealed that B10-B30 blends generated marginally higher performance and reduced exhaust emissions.

Dwivedi et al. [5] “Analyzed diesel engine Performance and emission evaluation utilizing biodiesel from several oil sources. Their findings have been important reduction of HC and CO and Boost NOX with Biodiesel when compared to petrol. The emission varies contrast between B100 and B20 fuels have been outlined. The reduction of HC emissions are 67% and 20 percent for B100 and B20 fuels respectively. The CO emission reductions are 48% and 12 percent for B100 and B20 gas respectively. However, the growth of NOX emission for B100 and B20 gasoline are 10% and 2% respectively compared to petrol gas. From their analysis, it was concluded that the substantial decrease in emissions were seen with B20 mix fuel”. Murugesan et al. [6] “directed to examine the prospects of introducing vegetable oils and their derivatives as fuel in gas motor. Their results show that using biodiesel in a conventional diesel motor caused substantial decrease in unburned HC and CO”.

Evangelos G. Giakoumis [7] “conducted a more comprehensive statistical evaluation so as to estimate the typical values of all physical and chemical properties of the majority of biodiesels. Twenty six distinct biodiesels containing four creature fat biodiesel properties ware investigated in his analysis. In his analysis, he said that the B20 fuel mix is the hottest mix”. In addition, he said in his analysis that the reduced density of gasoline exerts lower NOX emission. The analysis of Tomic et al. [8] will be contrasted to the exhaust emission of sunflower biodiesel using fossil fuel at a 4-cylinder, DI using 48kW ranked power engine. The exhaust gas emission indicated that the accession of biodiesel decreased the material of CO in addition to EGT, however, it raised the NOX.

K Srinivasa Rao et al. [9] analyzed diesel engine performance and emission characteristics fueled by wheat methyl ester. They detected decreased BTE, raised BSFC, diminished HC & amp; CO and raised NOX with corn methyl ester when compared with diesel Sehmus Altun (2011) [10] “analyzed performance and exhaust emissions of a DI diesel engine fueled by waste cooking oil and inedible animal tallow methyl ester. The experimental results demonstrated compared with gas, biodiesel fuels led to decrease in brake torque, an increase in brake specific fuel consumption and decrease in carbon monoxide”.

2. MATERIALS AND METHODS

The current work is focused to examine the several attributes of biodiesels in comparison with petroleum diesel and also studied compression and performance characteristics of lone cylinder 4-sroke direct injection gasoline engine fueled by numerous biodiesels and contrasted with Petroleum gas (PD) functioned attributes. The features Brake Thermal Efficiency (BTE), Brake Specific Fuel Consumption (BSFC), Carbon dioxide (CO), UN burnt hydro carbons (HC) and oxides of nitrogen (NOX) were considered to be the analysis and also compared with that of regular diesel controlled attributes.

2.1 Fuel Properties

The various biodiesels made from vegetable oils from transesterification procedure were utilized to test the diesel motor for

this particular investigation. The possessions of SFBD, PBD, CBD and WCBD and ASTM constant specification for biodiesel is shown in the table 1.

Table 1: Properties of Various Biodiesels Compared with PD

Property	Unit	PD	SFBD	RBD	CBD	WCBD	ASTM Standards(D6751)
Density	g/cc	0.831	0.859	0.884	0.878	0.88	0.87-0.89
Viscosity at 40°C	cSt	2.58	4.98	5.46	5.38	5.4	1.9-6.0
Flash Point	°C	50	158	163	160	166	130 minimum
Calorific value	kJ/kg	42500	38870	38590	37980	38100	37500
Cetane number	-	48	52	55	56	51	48-70
Iodine value	g Iodine/100 g	38	102	113	99	108	120 maximum
Acid value	mg KOH/g	-	0.32	0.36	0.41	0.39	0.5 maximum
Degree of unsaturation	-	-	1.02	1.36	1.18	1.34	-
chain length	-	-	17.92	17.69	17.58	17.84	
Oxidation stability	H	-	4.7	5.0	5.2	4.3	> 3 h
C	%	87	77.83	76.61	76.9	76.9	-
H	%	13	11.02	11.97	11.98	11.88	-
O	%	0	10.61	10.42	10.77	10.98	-

2.1.1 Density

"The grade of a substance or fluid is defined as its mass per unit volume. Many researchers favor the dimensionless expression specific gravity, and this can be described as the proportion of the density of a material to the density of a reference material generally water. Biodiesel fuels are also, generally characterized by greater density compared to traditional petroleum gas, meaning volumetrically-operating gas pumps will inject increased bulk of biodiesel than traditional diesel fuel. This in turn can impact the atmosphere –fuel ratio consequently the neighborhood gas temperatures and NOx emissions. In fact, it's been claimed that there is a correlation between density and NOx emissions, and together with reduced densities favoring lower NOx. Density increases with the rise in the amount of dual bonds, meaning that the more palatable the appearing petroleum. The greater the density of those based methyl ester, and the higher the gas mass which will be recovered in case a diesel-tuned engine has been run on biodiesel".

2.1.2 Kinematic Viscosity

"Viscosity is a measure of the resistance of a fluid that has been deformed by either shear or tensile stress. As an example of liquid fuels, the less viscous the liquid is, the higher its simplicity of motion (fluidity). In a diesel engine, greater viscosity contributes to less precise performance of the fuel injectors, also to weaker atomization of the fuel spray; those inefficiencies are more rigorous during chilly start. Additionally, the reduced gas leakage declines in the (mechanical) fuel pump because of high kinematic viscosity lead too to high injection pressures and, therefore, mass of compressed fuel".

2.1.3 Heating Value/Calorific Value

"The heating values are steps of fuels heat of combustion. Biodiesel features on average 10−12 percent w/w oxygen, which then results in proportionally lower energy density and heating power, hence more fuel must be pumped so as to attain the same motor power output. The greater the air content, thus the lower the heat worth".

2.1.4 Cetane Number

"Among the most powerful properties of this gas is that the dimensionless Cetane Number (CN), which signifies the ignitability of this gas, especially crucial during cold starting states. Low cetane numbers result in extended auto delay, and

i.e. long time between fuel injection and start of combustion. Thus, it reduced your CN the more sudden the premixed combustion period, resulting in addition to high combustion sound radiation. On the flip side, higher cetane numbers encourage quicker auto-ignition of their fuel. The cetane number of biodiesel is generally higher than that of the traditional diesel fuel. In addition, it has been contended that the impact of mixing biodiesel around the CN is roughly linear for combinations of biodiesels with diesel fuel. To get biodiesels Cetane number falls as the amount of double bonds rises".

2.1.5 Iodine Value

"The iodine number is a parameter used to ascertain the amount of unsaturation in biodiesels. This amount suggests the mass of potassium in g that is essential to fully saturate, by way of a stoichiometric response, the molecules of 100g of oil that is given. The specifications demand which biodiesels employed in compression ignition engines have a maximum value of Iodine value of their sequence of 120. The theory behind the specification is that large fuel iodine values signify propensity for polymerization leading to deposit creation. This usually means that a number of the researched FAMEs need to be excluded from usage in pristine form in motors. Diesel has quite low nutritional value, whereas biodiesels possess greater. Thus the amount of unsaturation is greater for biodiesels in comparison to diesel".

2.1.6 Oxidation Stability

Among the major problems that restrict the usage of biodiesel as a fuel in compression, ignition engines has its own inadequate oxidation stability. It's observed that just a number of the researched biodiesels meet the ASTM supply of 3h chemical equilibrium.

The fatty acids composition of the biodiesel is given Table 2. From the fatty acid composition of biodiesels it is observed that poly unsaturated fatty acids of WCBD > RBD > CBD > SFBD. Hence possibility of NO_X emission may also be arranged accordingly.

Table 2: Fatty Acid Composition of Biodiesels

Fatty Acid	Wt (%)			
	SFBD	RBD	CBD	WCBD
Myristic (14:0)	0.78	0.06	0.67	0.05
Palmitic (16:0)	24.01	12.81	15.69	8.27
Palmitoleic (16:1)	3.65	0.12	0.73	0.06
Stearic (18:0)	5.42	2.13	5.14	2.93
Oleic (18:1)	43.43	29.32	42.84	21.77
Linoleic (18:2)	20.83	55.71	30.36	65.75
Linolenic (18:3)	1.06	1.60	2.03	0.15
Eicosenoic (20:1)	0.41	0.36	0.56	0.13

2.2 Test Engine Setup

Single cylinder, 3.72 kW rated power, direct injection, naturally aspirated, water cooled, continuous speed (1500 rpm), stationary CI engine combined with eddy current dynamometer can be employed for the experimental analysis. The comprehensive technical specifications of this motor are provided in the table 3. The experimental arrangement used for the analysis is shown in figure 1. The setup includes

- Single cylinder diesel engine.
- Eddy current dynamometer to measure load torque or power.

- Data acquisition system to read all required data.
- Display panel to display all necessary temperatures, air flow and fuel consumption, etc.
- Computer to record all necessary data.

Figure 1: Experimental Setup.

Table 3: Engine Specifications

Manufacture and type	Kirloskar Oil Engine and AV1
Engine	Single Cylinder Direct Injection Compression Ignition
Admission of air	Naturally aspirated
Bore / Stroke & Compression ratio	80 mm / 110 mm & 16.5:1
Max power / Rated speed	3.72 kW / 1500 rpm
Dynamometer	Eddy Current Dynamometer
Method of cooling & Type of starting	Water cooled & Type of starting

2.3 Exhaust Gas Analyzer

INDUS made version 205, exhaust gas analyzer can be utilized to explore emission attributes. Carbon mono oxide (CO), Hydro carbon (HC) and oxides of nitrogen (NO_X) emissions could be quantified using exhaust gas analyzer. The analyzer utilizes the rule of Non-Dispersive Infra-Red (NDIR) for dimensions. Figure 2 demonstrates the exhaust gas analyzer employed with this process. The technical specifications of exhaust gas analyzer are provided in Table 4.

Figure 2: Exhaust Gas Analyzer

Table 4: Exhaust Gas Analyzer Specifications

Exhaust Gas Analyzer make and model: INDUS make and PEA 205		
Type of Emission	**Range**	**Resolution**
NO_X (ppm)	0-5000	1
HC (ppm)	0-15000	1
CO (%)	0-15.0	0.01

3. RESULTS AND DISCUSSIONS

The comparisons among biodiesels SFBD, RBD, CBD and WCBD compared to PD in terms of engine performance and emission characteristics are explained as follows.

3.1 Brake Thermal Efficiency (BTE)

Figure 3 shows the variation BTE with engine load for all fuels. It is observed that BTE for all fuels increases with load. Figure 4 indicates % change of BTE at 3.72 kW engine load for all fuels compared to PD. BTE of engine when running with biodiesels is lower than operated with PD. 8.06, 9.01, 12.43 and 10.48% of lower BTE were observed with SFBD, RBD, CBD and WCBD compared to PD. The lower heating values of biodiesel is the main reason for lower BTE values.

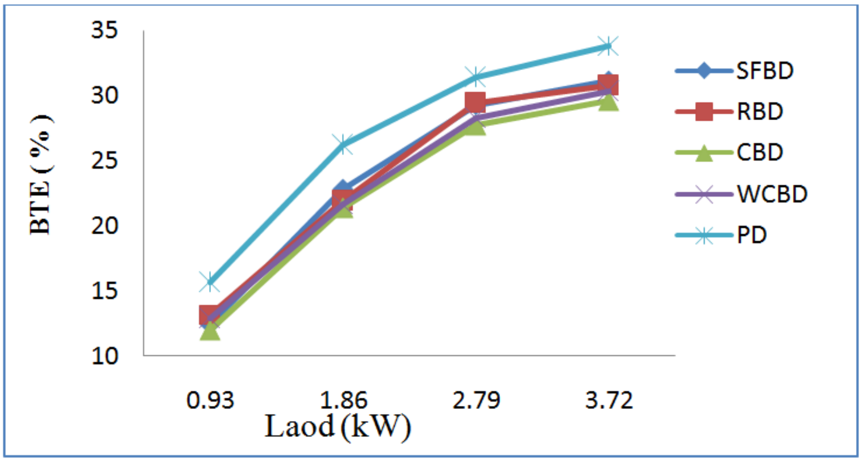

Figure 3: Variation of BTE at different Power Output.

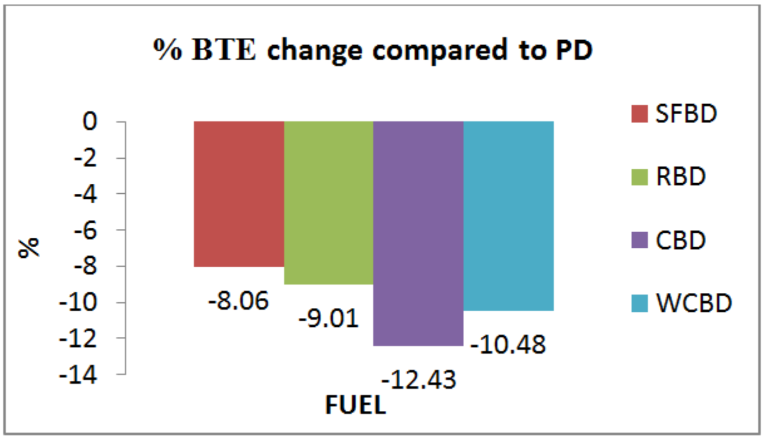

Figure 4: % of BTE Change Compared with CFBD at 3.72 kW Load

3.2 Brake Specific Fuel Consumption (BSFC)

The variation of BSFC of all biodiesels and PD with engine load is shown in figure 5. The percentage change of BSFC of all biodiesels in comparison with PD is also given in figure 6. It is observed from the figures that the BSFC of biodiesels are slightly higher compared to PD. The energy stored of the fuel which is liberated during combustion is low for biodiesel compared to PD. With 15.16%, the BSFC change of SFBD is less compared to other biodiesel.

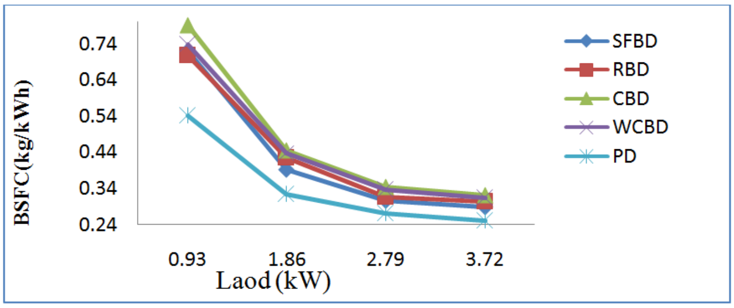

Figure 5: Variation of BSFC at different Power Output

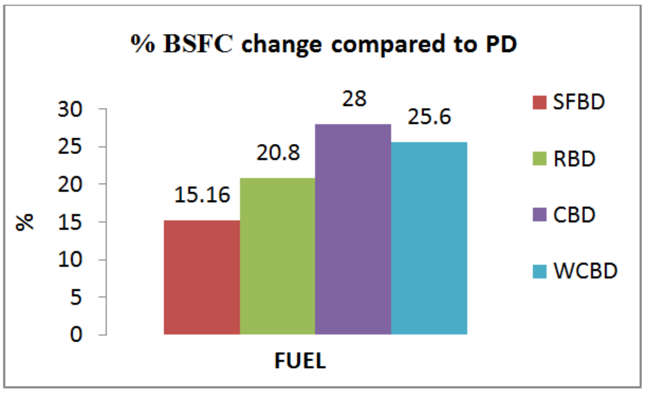

Figure 6: % of BSFC Change compared with CFBD at 3.72 kW Load.

3.3 Oxides of Nitrogen (NO_X)

The variation of NO_X emission of the test engine when operated with biodiesels compared to diesel is describe in figure 7 and percentage change of NO_X of all biodiesels compared to diesel is shown in figure 8. NO_X emissions of all biodiesels are quite higher compared to PD at all loading conditions and increase in load also increases NO_X emission. Among all WCBD NO_X emission are more compared to all other biodiesel. 25.1, 29.2, 28.4 and 30.2% higher NO_X emission were observed with SFBD, RBD, CBD and WCBD respectively compared to PD at full engine load. The higher poly unsaturated fatty acid composition and more oxygen content are main reason for higher NO_X emission for biodiesels

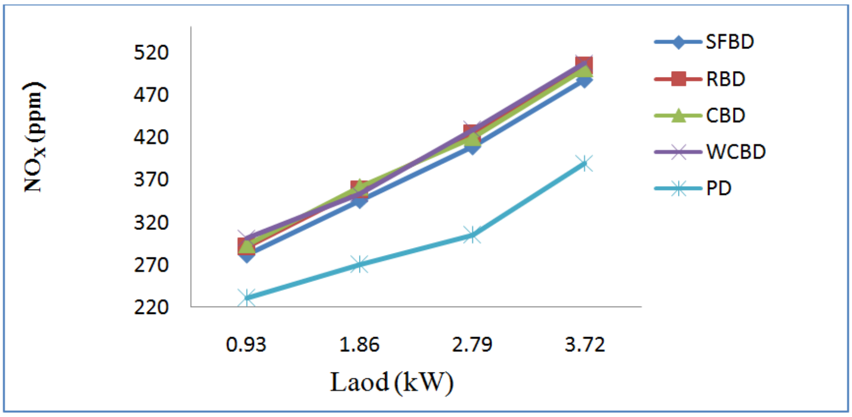

Figure 7: Variation of NO_X at different Power Output.

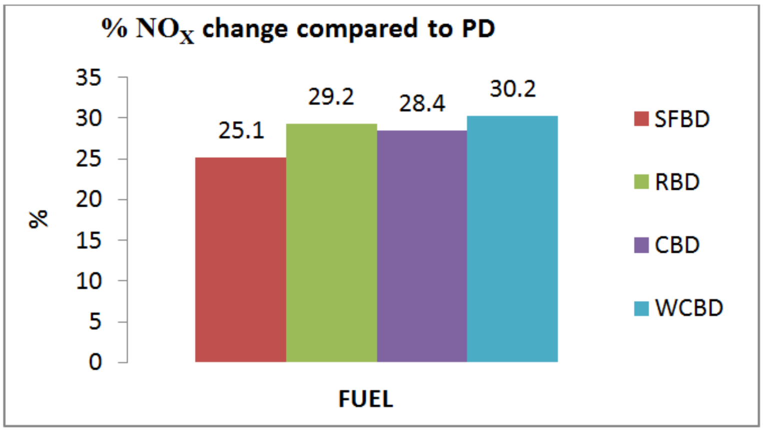

Figure 8: % of NO_X Change Compared with CFBD at 3.72 kW Load

3.4 Hydro Carbon Emission (HC)

The HC emission variation of all biodiesels and PD with engine load is shown in figure 9 and percentage change of HC emission compared to PD is illustrated in figure 10. From these figures, it was observed that the engine emits quite lower HC emission for all biodiesels compared to PD. CBD produces very low HC emission of 36.5% compared to PD. The lower HC emission of all biodiesels are mainly due to presence of more oxygen results complete combustion leading to lower HC emission.

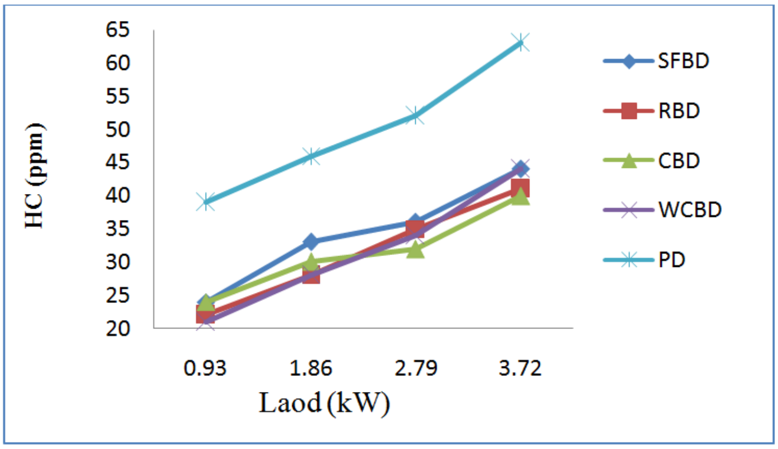

Figure 9: Variation of HC at different Power Output.

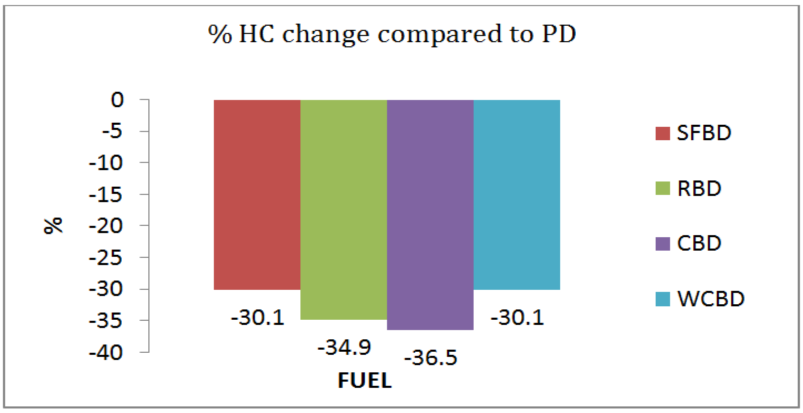

Figure 10: % of HC Change Compared with CFBD at 3.72 kW Load.

3.5 CO Emissions

Figure 11 and 12 clearly explain the variation of CO emission of all biodiesels and PD with engine load and percentage change of CO emission of all biodiesels compared to PD. CO emission increases with load and WCBD observes lower CO emission at all loading conditions. At full load 17.3, 21.7, 21.7 and 26% lower CO emission were recorded with SFBD, RBD, CBD and WCBD respectively compared to PD. The presence of more oxygen in biodiesel results complete combustion, which is the main reason for lower CO emission compared to PD.

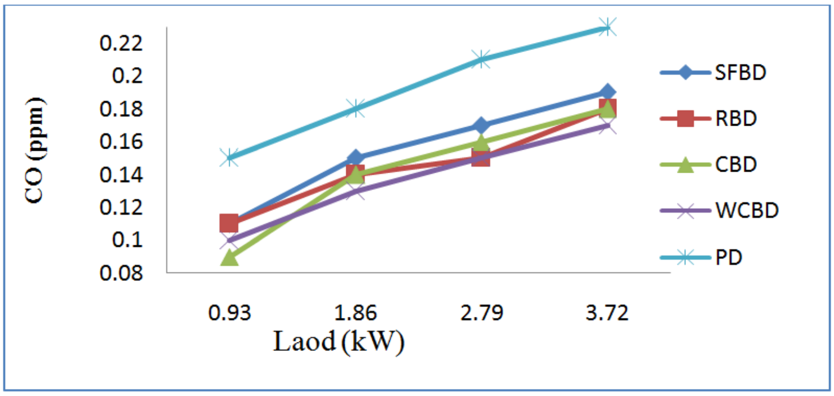

Figure 11: Variation of CO at different Power Output.

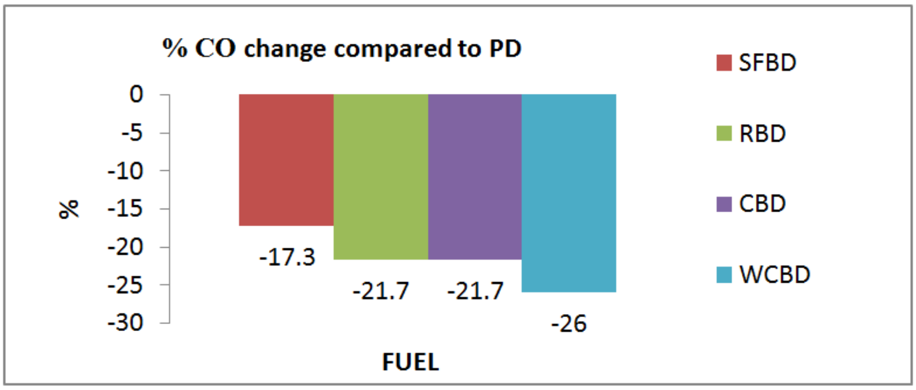

Figure 12: % of CO change Compared with CFBD at 3.72 kW load

4. CONCLUSIONS

The comparative performance and emission characteristics of SFBD, PBD, CBD and WCBD compared to PD have been analyzed and the following conclusions are drawn:

- Slightly lower BTE and higher BSFC were observed for all biodiesels compared to PD. SFBD records higher BTE and lower BSFC compared to all other biodiesels. Calorific value is main reason for this variation.
- Observed higher NO_X emission for all biodiesels compared to PD. The highest NO_X emission was measured for WCBD which is 30.2% higher compared to PD. This is mainly due to higher poly unsaturated fatty acid content in fuel.
- Considerably lower HC and CO emissions were recorded with all biodiesels compared to PD. 36.5% lower HC emission and 26% CO emission were observed with CBD and WCBD compared to PD at full engine load. The presence of more oxygen is the reason for lower HC and CO emission for all biodiesels.

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